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2 TITLE: APPARATUS AND METHOD FOR VALIDATING WIRING
3 DIAGRAMS AND CREATING WIRE LISTS
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6 BACKGROUND OF THE INVENTION

7 1. Field of The Invention

8 The present invention relates to electronic test
9 equipment used to test wires and wiring harnesses.

10 2. Description of the Related Art

11 There are few effective systems for validating the
12 integrity and accuracy of a wiring harness based upon an
13 existing wiring diagram or wiring list. Most such
14 systems currently in use are both extremely expensive and
15 complex. Systems capable of verifying continuity in a
16 wiring harness are generally designed to be utilized by
17 at least two technicians positioned at either end of the
18 wiring harness under investigation.
19

20 SUMMARY OF THE INVENTION

21 It is an object of the present invention to provide
22 a novel piece of equipment and method to validate the
23 accuracy of wiring diagram manuals.

24 It is another object of the present invention to
25 create wire lists.

26 It is another object of the present invention to
27 provide improved and automatic wiring continuity checks.

28 It is another object of the present invention to
29 allow a single user to validate accuracy and create wire
30 lists.

31 It is another object of the present invention to
32 test modifications and new installations.

33 It is another object of the present invention to
34 provide improved and automatic wiring insulation checks.

1 It is another object of the present invention to
2 provide a system for improved and automatic wiring
3 continuity checks and generating a wiring diagram
4 reflecting the same.

5 In satisfaction of these and related objectives, the
6 present invention provides a portable and easy to use
7 tester for validating the accuracy of wiring diagram
8 manuals and for testing modifications and new
9 installations for proper wiring. The invention also
10 provides an easy way to create a wire list describing all
11 the interconnections between attached connectors. The
12 tester can also be used as a troubleshooting tool without
13 having a previously learned cable reference. The
14 invention further tests wiring insulation in a wiring
15 harness and identifies poor wire to wire and wire to
16 ground insulation. Finally the present invention
17 provides a system for generating a wiring diagram based
18 upon the results of a wiring validation series of
19 checks/tests.

20
21 BRIEF DESCRIPTION OF THE DRAWINGS

22 Fig. 1 is a flow chart of the wiring validation
23 process of the preferred embodiment.

24 Fig. 2 is a flow chart of the wire list generation
25 process of the preferred embodiment.

26 Fig. 3 is a diagram of the electronic circuitry of
27 the preferred embodiment.

28 Fig. 4 is a diagram of the electronic circuitry of
29 the basic sensor of the preferred embodiment.

30 Fig. 5 is an example of the wire list attributes
31 used in the preferred example.

32 Fig. 6 is a schematic block diagram showing the
33 arrangement and function of the various hardware
34 components of the present invention.

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

2 The present invention provides an easy to use
3 Windows[®] based software to validate the accuracy of wiring
4 diagram manuals and wiring diagram drawings. The
5 equipment of the system of the invention will
6 automatically create wire lists, automatically learn
7 wiring configurations, test modifications and new
8 installations, and automatically creates reports in MS
9 Access 97 format. In addition, the system will sense
10 wiring insulation integrity and may interface with
11 computer aided drawing software to generate accurate
12 wiring diagrams. The reports generated will show total
13 cables tested, failed, percentage and creates a summary -
14 final acceptance form. The equipment will save files to a
15 computer hard drive and/or floppy disk, read files from
16 computer hard drive, CD-ROM or floppy disk, and import
17 wire list data in MS Access[®] 97 to be used as a baseline.
18 As a result, the invention improves and automates wiring
19 continuity checks, allows for use by a single technician,
20 and the open architecture design allows system expansion.

21 The basic operation of the system involves the
22 "learning" of a known good wiring harness, thereby
23 establishing a baseline reference, and thereafter testing
24 the wiring harness against this reference. The system,
25 however, may also be used as a trouble shooting tool
26 without having previously learned cable as a reference.
27 The user can compare the wire list generated by the
28 system and very quickly compare it with the "proper" wire
29 list to identify deviations from the norm.

30 The primary validation is that of proper connections
31 though additional wiring harness characteristics can be
32 easily acquired by the present system. The properties of
33 the insulation associated with the wiring harness are
34 discernable by varying the interrogating voltage between

1 the wires under test and between any wire and the system
2 ground. The resistivity of the wires within the wiring
3 harness is also discernable with the same basic
4 functional electronic interrogating circuits.

5 In addition to written reports in the form of wire
6 lists and tables of wiring harness characteristics, the
7 present invention incorporates software features that
8 permit the generation of wiring diagrams based on the
9 stored results of the testing operations carried out.

10 The goal of the system is to report on the condition
11 of the wiring harness under test. The system generates a
12 number of reports useful to the operator, including:

13 Pass/Fail Report that identifies the number of
14 wires tested, the number of wires that passed, the number
15 of wires that failed, and the percentage of cables that
16 passed.

17 Failure Report that responds to queries from the
18 user to identify more specifically the failed elements
19 and their failure parameters.

20 Wire List Report that may be generated at any point
21 in the process and/or in response to the user selecting a
22 specific part for investigation.

23 Summary Report that provides in summary form the
24 results of all or a select group of tests carried out
25 over a period of time.

26 THE CIRCUITRY

27 The connectors of the wiring harness under test are
28 connected to the system connectors. The hardware
29 provides via a switching circuitry a small voltage,
30 typically 1 volt, as stimulus. It then senses the current
31 through the wire and determines if there is a connection.
32 A variable and software controlled reference voltage is
33 used to determine the sensitivity of the test and may be

1 used to find the resistance of the wire. The results for
2 each wire are then stored in the computer memory.

3 Software algorithms create a wire list, which is the
4 "map" or the diagram of the harness. If the wire list was
5 created from a known good harness, it may be used as a
6 base line reference for testing other wire harnesses from
7 the same type.

8 WIRING VALIDATION

9 The main feature of the system of the present
10 invention is its ability to validate the accuracy of
11 wiring diagram manuals. Wiring diagrams of legacy
12 aircraft do not always reflect the actual wiring
13 installed. This may cause difficulties in maintaining and
14 troubleshooting the aircraft. Validating the wiring
15 diagrams using Ohm-meters, requires two technicians, is
16 time consuming and expensive.

17 Typically, the wiring diagram in a manual is stored
18 in database format and the fields of the database include
19 the part number of the harness, the wire identification,
20 the length, name of start plugs, end plugs, references
21 and more.

22 The system software can import the original database
23 file i.e. an MS Access 97 database file, and goes through
24 the following process:

- 25 1. Copies the original database to a temporary
26 file.
- 27 2. Sort it by connector name with the highest pin-
28 count pins within the connectors will be sorted in
29 ascending order.
- 30 3. Assign original pin identifications within the
31 connector to system pin identifications.

32 Example: 757DM9240 Terminal 10 is assigned to
33 system DM9240 pin 43. Note: If the original pin

- 1 (terminal) is a character (as aa, b, z) it will
2 translated to a numerical value.
- 3 4. Assign modules to above referenced connectors.
4 If more then 32 pins are being examined, combine
5 modules.
- 6 5. Create original to system interface diagram.
- 7 6. Based on 'Conn1KtestPin7' and 'Conn2KtestPin"
8 (see item 4) it creates a Ktest LEARN format
9 records and save to Ktest random access tile.
- 10 7. Run test.
- 11 8. Create wire-list database in same format as
12 original. This one will contain actual wire-list.
- 13 9. If test fails, it will show the difference
14 between original wire-list and the actual wire-
15 list.

16
17 By taking the above steps, the system of the present
18 invention imports the original database with all its
19 fields, (which could also include fields like wire color,
20 gauge, dates and so on).

21 After the system testing operation, the system will
22 export the same database file structure with all its
23 original fields but with the indication that the wiring
24 was either validated or will show the differences between
25 the imported database and the actual results. Upon
26 request, a corrected database file can be automatically
27 created.

28

29 WIRE LIST PROCESS

30 Reference is made to Fig. 2 for a brief description
31 of the method for creating a wire list through operation
32 of the system.

33

- 1 1. The controller sends a command to the Driver/Sensor
2 cards to select two wires.
- 3 2. The controller gets a voltage level from the
4 Driver/Sensor card which corresponds to the status of
5 the 2 wires (short or open).
- 6 3. The system measures the value of Item 2 above,
7 compares it to a set reference and determines the
8 status (short/open).
- 9 4. The system stores the status result of the selected
10 two wires in a database and proceeds with the next set
11 of wires.
- 12 5. Upon completion selecting and testing all wires
13 connected to the system, the
- 14 6. software sorts its database and creates a list of all
15 the wires which were found to be connected to each
16 other.

17 18 VALIDATION PROCESS

19 Reference is made to Fig. 1 for a general
20 description of the validation process of the present
21 invention.

- 22
- 23 1. A database file containing wiring data is imported
24 into the system Test Import program.
- 25 2. The Program, using Visual Basic 5 copies the original
26 file to a temporary file.
- 27 3. The program then assigns the database fields required
28 by the system to the temporary database file. These
29 fields are Cable Number 1 Connector 1 Name, Connector
30 1 Terminal, Connector 2 Name, Connector 2 Terminal.
- 31 4. The program counts the number of pins assigned to each
32 Connector, arranges them in ascending order and
33 assigns them to system pin numbers, so they can be
34 accessed by the system controller card.

- 1 5. The program then assigns to the connectors the
2 appropriate system connector modules, so for example
3 If the connector has 50 pins, there will be 2 modules
4 assigned.
- 5 6. The program reads from the database the records which
6 shows Cable Number, Connector 1 Name, Connector 1
7 Terminal, Connector 2 Name, Connector 2 Terminal and
8 based on that information which shows which system pin
9 number connects to another system pin number, it
10 creates a system equivalent "learn" file which is
11 structured in the same way as a regular (with no
12 database input) cable under test file.
- 13 7. At this point the system is capable of running a
14 regular test on the harness under test.
- 15 8. The results of these tests are written back into the
16 records of the database in new added fields which now
17 represent the "actual" Connector 2 Name, and the
18 "actual" Connector 2 Terminal. In other words, new
19 fields to the database were added only to Connector 2
20 Name, and Connector 2 Terminal because they represent
21 a potential difference to where Connector 1 could
22 actually be connected to.
- 23 9. The program compares the "actual" results to the
24 expected results (stored in the old Connector 2 Name,
25 and Connector 2 Terminal). If the results are the same
26 then the wire harness is validated. If they are not
27 the same, the program translates the fields back to
28 the original database format and field names, and
29 provides a new corrected database file for the wire
30 harness. The user gets a corrected database and still
31 retains the information of the other fields not needed
32 by the system (such as wire color, wire gauge etc.).
33 In addition, 2 fields which show differences are
34 added.

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2

HARDWARE DESCRIPTION

3 The hardware of the system of the present invention
4 consists of two primary components: the Controller Card
5 which resides inside the IBM PC type computer and the
6 Multiplexer/Driver cards which reside inside the system
7 connector unit and which are controlled by the Controller
8 Card. Standard PC architecture is required for
9 integration and operation of all of the features of the
10 system of the present invention.

11 The Controller Card:

12 The Controller card resides inside the IBM PC type
13 computer, connected to the computer bus. The system
14 circuitry is able to select any 2 points of the
15 multiplexer/driver card. Since the wire harness under
16 test is connected directly to the multiplexer/driver
17 card, the controller can select any 2 wires of the
18 harness under test. The process is as following;

- 19 1. The controller sends a command to the
20 multiplexer/driver card to select 2 wires.
- 21 2. The controller gets a voltage level from the
22 multiplexer/driver card which corresponds to the
23 status of the 2 wires (short or open).
- 24 3 The system measures the value of item 2, compares it
25 to a set reference and determines the status
26 (short/open).
- 27 4. The system stores the status result of the selected 2
28 wires and proceeds with the next set of wires.

29

HARDWARE COMPONENTS

30 Reference is made to Fig. 3 for a description of the
31 electronic components of part of the system of the
32 present invention.

33 P1 is the IBM ISA bus connector.

1 U4 provides signals which make selections at the
2 multiplexer/driver card.
3 U1, U2, U5, U6, U7, and U33 are buffers and registers for
4 bus and selection signals.
5 U31 and U36 are voltage regulators which provide a
6 reference voltage to the DAC U30.
7 U35 is a constant current source which is applied to the
8 multiplexers at the multiplexer/driver card. This is the
9 actual current source which is applied to the wires under
10 test.
11 U34 and U35 are differential amplifiers which amplify the
12 signal from the multiplexer/driver card.
13 U10 compares the level of the amplified signal from the
14 multiplexer/driver card to a reference voltage from DAC
15 U30 (Digital to Analog Converter), and makes decision if
16 the wires under test are shorted or opened. The output of
17 the comparator U10 is connected to the computer bus to
18 register the result to a computer file.

19 The Multiplexer/Driver Card

20 The multiplexer/driver card connects to the wire
21 harness under test via multiple connector modules located
22 on top panel of the system connector unit. Each
23 connector can connect up to 32 wires. If the harness
24 under test requires more than 32 contacts per connector,
25 multiple connector modules may be combined and form a
26 larger connector. As an example, two combined connector
27 modules will have 64 pins. The software recognizes the
28 combined connector modules and assigns them the right
29 number of pins.

30 The hardware of the multiplexer/driver card consist
31 of control logic components U17, U18, U38 and U39 which
32 steer the signals from the Controller Card to the
33 selected pair of wires under test. U1 - U16, U21 - U36
34 are multiplexer IC's, which are connected to the wire

1 harness under test. These IC's are arranged in 2 groups
2 as shown in Figs. 3 and 4: Rail A and Rail B. Two
3 multiplexer/driver cards are needed for every 128 points.
4 One card provides the stimulus for the selected 2 wires
5 (between Rail A and Rail B). The other card senses the
6 signals (between Rail A And Rail B) and sends them to the
7 controller card for evaluation.

8 INSULATION TESTING

9 The system of the present invention, using the
10 same basic hardware components, further provides a
11 means for determining the integrity of the wiring
12 harness insulation by detecting leakage in aircraft
13 wiring, caused by faulty insulation and testing the
14 strength of the wiring insulation.

15 Faulty insulation, caused by aging or chafing, may
16 cause the discharge of sparks and arcing between
17 conductor to conductor or conductor to frame. When a
18 cable harness is tested, the system of the present
19 invention measures the leakage current between each
20 conductor to aircraft structure and to the other
21 conductors by measuring a leakage current and providing
22 results in magnitude of gigaOhms.

23 Typically the test is conducted in two steps:

24 First, a low voltage source of 10VDC is used to
25 determine low voltage leakage between any wire to
26 aircraft structure and to the rest of the wires. A
27 threshold can be set such that wires with less than, for
28 example, 2 or 5 gigaOhms will be reported.

29 The second step, allows testing the wires not reported
30 as failing in the first step, to be tested under higher
31 voltage, typically 500VDC (the voltage is programmable, and
32 so is the duration). Also in this step a threshold can be
33 set such that wires with less than, for example, 20 gigaOhms
34 will be reported. The higher voltage, detects weak insulation

1 and can measure higher values of leakage/ resistance than the
2 previous step.

3 In the disclosed configuration, the system of the
4 present invention may connect to 512 points, in which only
5 the first 64 can test for high voltage. In addition, there
6 are safety features alerting the user to the higher voltage
7 while testing in high voltage mode. In addition to software
8 controlled switching, a manual cut off switch is also
9 installed in the system. The design of the system, however,
10 allows for increasing the number of points if required.

11 In addition the system of the present invention
12 incorporates a resistivity measurement capability to
13 supplement the wire validation process. In a resistivity
14 testing mode the user can select a resistance value. Then
15 all wires with resistance above the specified value will
16 register as faulty during test.

17 Alternately, the user can select two limits for
18 resistance values: an upper limit and a lower limit.
19 Wires with resistance outside these limits will register
20 as faulty during test.

21 Further selectable components of the hardware of the
22 present invention, components and functions which are
23 known in the art, provide the following additional
24 features:

25 Low Voltage Leakage: The user can select a high
26 resistance value, for example 1000 Mega Ohm. The tester
27 uses low voltage of about 10VDC to make the measurements.
28 All wires with resistance above the specified value will
29 register as faulty during test.

30 High Voltage Leakage: The user can select a high
31 resistance value, example 5000 Mega Ohm. The tester uses
32 high voltage, programmable by user, for example 1 - 500
33 VDC to make the measurements. All wires with resistance
34 above the specified value will register as faulty during

1 test. The user can also specify the duration of the
2 present of the high voltage from 1 to 60 seconds. In
3 addition, the hardware and the software ensure that a
4 high voltage leakage test can be performed only on wires
5 which did not fail the low voltage leakage test. The
6 presence of the high voltage is controlled by software
7 and hardware. At any time the user can cut off the
8 voltage using a switch located on the front panel of the
9 tester.

10 Using a high voltage is also necessary to check the
11 strength of the insulation. Weak insulation will show a
12 lower than normal resistance between the faulty wires.

13 Create Drawings Function: This function commands the
14 tester function of the present invention to capture and
15 store all the interconnections of all wires connected to
16 the system. The system then translates the captured data
17 to drawings. The software can generate files in AutoCad®
18 format or in different formats for CAD/CAM, etc. The
19 software assigns one or more pages to the drawings, based
20 on the number of connectors and number of wires involved.
21 If several pages are involved, and a wire connects to a
22 connector on a different page, the software adds a label
23 to the wire with the target page number.

24 Edit functions: The user can edit the name of each
25 wire, and can select individual wires to be tested, by
26 checking the check boxes next to each wire.

27 The software system for generating wiring diagrams
28 is an object oriented system and addresses the following
29 objects:

30 Schematic (Object)

31 Comprises a collection of pages

32 Comprises a collection of connections

33 Comprises a collection of connectors

- 1 Can assign connectors to pages .
- 2 Can generate files in different formats (for
- 3 CAD/CAM, etc.)
- 4 Page (Object)
- 5 Comprises one or more connectors.
- 6 Can respond to a connector request to draw itself by
- 7 drawing the connector
- 8 Can respond to a connector request to draw a
- 9 connection (to another connector or to the edge of
- 10 the page (with a label))
- 11 Connector (Object)
- 12 Knows its size (number of pins), its page, and its
- 13 page location
- 14 Can ask his page to draw itself
- 15 Can ask his page to draw a connection from one of
- 16 his pins to another connector
- 17 Connection (Object)
- 18 Knows its two connectors and pin numbers
- 19 Can ask its connectors for their pages
- 20 Can ask one of its connector to draw the entire
- 21 connection (if both connectors are on the same
- 22 page)
- 23 Can ask each of its connectors to draw part of the
- 24 connection (if both connectors are not on the same
- 25 page)
- 26 The process carried out by the system in order to
- 27 create a usable wiring diagram, in conjunction with
- 28 standard CAD/CAM software packages, is as follows:
- 29 1. The Schematic object analyzes the number and size of
- 30 its connectors collection, creates the appropriate
- 31 number of pages, and assigns each page one or more
- 32 connectors.

1 2. The Schematic object iterates through its connectors
2 collection and tells each connector to draw itself,
3 and in turn, each connector tells its page to draw
4 the connector.

5 3. The Schematic object iterates through its
6 connections collection and tells each connection to
7 draw itself. Each connection in turns check if both
8 ends of the connection are on the same page or not.
9 If the page is the same, the connection asks one of
10 the connectors to draw the connections. The
11 connector in turn, asks its page to draw the
12 connection. If the page is not the same, the
13 connection asks each of the connectors to draw its
14 portion of the connection. The connector in turn,
15 asks its page to draw its part of the connection.

16 The hardware components of the present invention are
17 shown in schematic block diagram form in Fig. 6. This
18 view clarifies the arrangement where the controller card,
19 incorporated within the system computer, is linked to and
20 controls the operation of the multiplexer/driver cards
21 which are positioned within the system connector unit.
22 The multiplexer/driver cards are in turn connected to the
23 connector modules on the connector unit in the manner
24 described above. The wiring harnesses under test are
25 then connected to the connector modules as shown.

26 Although the invention has been described with
27 reference to specific embodiments, this description is
28 not meant to be construed in a limited sense. Various
29 modifications of the disclosed embodiments, as well as
30 alternative embodiments of the inventions will become
31 apparent to persons skilled in the art upon the reference
32 to the description of the invention. It is, therefore,
33 contemplated that the appended claims will cover such

1 modifications that fall within the scope of the
2 invention.

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